The+rate+constant+for+the+first+order+decomposition+of+a+at+500oc+is+9.2+x+10-3+s-1.+how+long+will+it+take+for+90.8%+of+a+0.500+m+sample+of+a+to+decompose?

The+rate+constant+for+the+first+order+decomposition+of+a+at+500°C+is+9.2+x+10^{-3}+s^{-1}.+How+long+will+it+take+for+90.8%+of+a+0.500+M+sample+of+a+to+decompose?

Understanding the First-Order Decomposition Reaction

First-order reactions are fundamental in chemical kinetics, especially in decomposition processes where the rate depends linearly on the concentration of a single reactant. When studying the decomposition of a substance at elevated temperatures, such as 500°C, the rate constant (k) provides crucial information for predicting the reaction's progression over time.

In this scenario, the rate constant for the decomposition of a particular compound at 500°C is given as 9.2 + x 10^{-3} s^{-1}. Although there's a small ambiguity with the notation "x," it is typically interpreted as a decimal point, leading to a rate constant of approximately 9.2 × 10^{-3} s^{-1}. This indicates that the reaction proceeds relatively quickly at the elevated temperature, and the kinetics can be modeled using first-order reaction equations.

Key Concepts in First-Order Reaction Kinetics

Understanding the kinetics requires familiarity with several fundamental concepts:

1. Rate Constant (k)

- Defines the speed of the reaction.
- Units typically in s^{-1} for first-order reactions.
- Higher k values imply faster reactions.

2. Integrated Rate Law for First-Order Reactions

- The concentration of reactant A at time t: $[A]_t = [A]_0 e^{-kt}$
- Where:
- $[A]_0$: initial concentration
- $[A]_t$: concentration at time t
- k: rate constant
- t: time elapsed

3. Fraction of Reactant Decomposed

- The fraction of reactant decomposed after time t:
- $f = 1 - ([A]_t / [A]_0)$
- For example, if 90.8% decomposed, then f = 0.908.

Calculating the Time for 90.8% Decomposition

The core of this problem is determining how long it takes for 90.8% of a 0.500 M sample of compound A to decompose at 500°C, given the rate constant.

Step 1: Express the Decomposition Fraction

Since 90.8% of the reactant decomposes:
- Remaining concentration: $[A]_t = [A]_0 \times (1 - 0.908) = 0.092 \times [A]_0$

Step 2: Apply the First-Order Rate Law

Using the integrated rate law:
$$ [A]_t = [A]_0 e^{-kt} $$

Substitute $[A]_t$:
$$ 0.092 \times [A]_0 = [A]_0 e^{-kt} $$

Dividing both sides by $[A]_0$:
$$ 0.092 = e^{-kt} $$

Step 3: Solve for Time (t)

Taking natural logarithm:
$$ \ln(0.092) = -kt $$

$$ t = -\frac{\ln(0.092)}{k} $$

Insert the value of k:
$$ k = 9.2 \times 10^{-3} \, \text{s}^{-1} $$

Calculate:
$$ t = - \frac{\ln(0.092)}{9.2 \times 10^{-3}} $$

Calculate the natural logarithm:
$$ \ln(0.092) \approx -2.386 $$

Therefore:
$$ t = - \frac{-2.386}{9.2 \times 10^{-3}} $$

$$ t \approx \frac{2.386}{9.2 \times 10^{-3}} $$

$$ t \approx 259.5 \, \text{seconds} $$

Final Answer: Time for 90.8% Decomposition

It will take approximately 259.5 seconds for 90.8% of a 0.500 M sample of the compound to decompose at 500°C, assuming the reaction follows first-order kinetics with a rate constant of 9.2×10^{-3} s^{-1}.

Additional Considerations in Reaction Kinetics

While the calculation provides a clear estimate, real-world reactions may involve additional factors:

Factors Affecting Reaction Rate:

- Temperature fluctuations
- Presence of catalysts or inhibitors
- Sample purity
- Reaction environment

Implications in Industrial and Laboratory Settings:

Understanding the time required for decomposition helps in process optimization, safety assessments, and designing appropriate reaction conditions.

Summary of Key Points

- The first-order rate constant at 500°C is approximately 9.2×10^{-3} s^{-1}.
- 90.8% decomposition corresponds to a remaining concentration of 9.2%.
- Using the first-order integrated rate law, the reaction time is about 259.5 seconds.
- This calculation assists chemists in predicting reaction completion times

under specified conditions.

Conclusion

Predicting the decomposition time of a reactant based on its rate constant is a vital aspect of chemical kinetics. By understanding the principles of first-order reactions and applying the integrated rate law, scientists and engineers can accurately estimate reaction times, optimize industrial processes, and ensure safety in handling reactive substances. In this case, knowing that it takes roughly 259.5 seconds for 90.8% of the compound to decompose at 500°C allows for better control and planning in applications involving thermal decomposition reactions.

SEO Keywords and Phrases for Optimization

- first order reaction kinetics
- decomposition rate constant
- reaction time calculation
- thermal decomposition at 500°C
- how long for 90.8% decomposition
- rate constant of chemical reactions
- integrated rate law
- chemical kinetics examples
- decomposition reaction time estimate
- temperature effects on reaction rates

By incorporating these keywords naturally throughout the article, it enhances visibility for users searching for related topics in chemical kinetics and reaction rate calculations.

Frequently Asked Questions

What is the rate constant for the first-order decomposition of substance A at 500°C?

The rate constant is 9.2 x 10^-3 s^-1.

How is the rate constant for a first-order reaction defined?

It is a measure of the speed at which a reactant decomposes, expressed in units of s^-1, indicating the fraction of reactant decomposed per second.

What is the initial concentration of A in the problem?

The initial concentration of A is 0.500 M.

How much of the sample decomposes when 90.8% has reacted?

When 90.8% decomposes, 9.2% remains, meaning 0.500 M x 0.092 = 0.046 M of A remains.

What is the first step to determine the time for 90.8% decomposition?

Calculate the remaining concentration after decomposition and then use the first-order kinetic equation to find the time.

What is the first-order kinetics equation used in this problem?

t = (1/k) ln([A]_initial / [A]_final).

How do you calculate [A]_final after 90.8% decomposition?

Multiply the initial concentration by the remaining percentage: 0.500 M x 0.092 = 0.046 M.

What is the value of the natural logarithm of the concentration ratio in this case?

ln(0.500 / 0.046) ≈ ln(10.87) ≈ 2.386.

What is the calculated time for 90.8% decomposition of the sample?

t = (1/9.2 x 10^-3) 2.386 ≈ 259.78 seconds, or approximately 4 minutes and 20 seconds.

Why is understanding the rate constant important for reaction kinetics?

It helps predict how quickly a reaction occurs, which is essential for process design, safety, and efficiency in chemical manufacturing.

Additional Resources

The rate constant for the first-order decomposition of a at 500°C is 9.2 × 10-3 s-1. How long will it take for 90.8% of a 0.500 M sample of a to decompose?

Understanding reaction kinetics is fundamental in chemistry, especially when predicting how long a chemical process will take under certain conditions. This article delves into the calculation of the decomposition time of a substance based on its rate constant, focusing on a first-order reaction at a high temperature of 500°C. We'll explore the principles behind first-order kinetics, derive the necessary equations, and provide a step-by-step method to determine the time required for a specific degree of decomposition.

Understanding First-Order Reactions

What Is a First-Order Reaction?

A first-order reaction is a type of chemical reaction where the rate depends linearly on the concentration of a single reactant. The general rate law for such reactions can be written as:

$$ \text{Rate} = k[A] $$

where:
- $[A]$ is the concentration of reactant A,
- k is the rate constant, a proportionality factor indicating how fast the reaction proceeds.

Because the rate depends solely on the concentration of one reactant, the kinetics of first-order reactions are straightforward to analyze and predict.

Characteristic Features

- The half-life ($t_{1/2}$), which is the time for half of the reactant to decompose, is constant and independent of initial concentration.
- The concentration decreases exponentially over time.

The general integrated rate law for a first-order reaction is:

$$ [A] = [A]_0 e^{-kt} $$

where:
- $[A]_0$ is the initial concentration,
- t is time.

Given Data and Objectives

Let's restate the problem with the provided data:

- Rate constant, $k = 9.2 \times 10^{-3} \, \text{s}^{-1}$
- Temperature: 500°C (although for this calculation, temperature is fixed and not directly involved in the equations)
- Initial concentration, $[A]_0 = 0.500 \, \text{M}$
- Desired decomposition: 90.8%
- Time to find: t

The goal is to determine the time t required for 90.8% of the initial sample to decompose, meaning only 9.2% remains.

Calculating the Time for 90.8% Decomposition

Step 1: Understanding Percent Decomposition in Terms of Concentration

Percent decomposition indicates how much of the initial reactant has reacted. Mathematically:

$$\text{Remaining concentration} = [A] = [A]_0 \times (1 - \text{percent decomposed})$$

Given 90.8% decomposed, the remaining percentage is:

$$100\% - 90.8\% = 9.2\%$$

Expressed as a decimal:

$$\frac{9.2}{100} = 0.092$$

Therefore, the remaining concentration after decomposition:

$$[A] = [A]_0 \times 0.092$$

Plugging in the initial concentration:

$$[A] = 0.500 \times 0.092 = 0.04584\, \text{M}$$

Step 2: Applying the First-Order Kinetics Equation

Recall the integrated rate law:

$$ [A] = [A]_0 e^{-kt} $$

Rearranged to solve for t:

$$ t = -\frac{1}{k} \ln \left(\frac{[A]}{[A]_0} \right) $$

Substituting known values:

$$ t = -\frac{1}{9.2 \times 10^{-3}} \ln \left(\frac{0.04584}{0.500} \right) $$

Calculate the ratio:

$$ \frac{0.04584}{0.500} = 0.09168 $$

Calculate the natural logarithm:

$$ \ln(0.09168) \approx -2.390 $$

Now, compute t:

$$ t = -\frac{1}{9.2 \times 10^{-3}} \times (-2.390) $$

$$ t = \frac{2.390}{9.2 \times 10^{-3}} $$

$$ t \approx 259.78\, \text{seconds} $$

Interpreting the Results

The calculation indicates that approximately 260 seconds, or about 4 minutes and 20 seconds, are needed for 90.8% of the initial 0.500 M sample of substance A to decompose at 500°C, given the rate constant.

This rapid decomposition underscores the high reactivity of the substance at elevated temperatures. It also exemplifies how kinetic parameters can allow chemists and engineers to predict process durations precisely, vital for designing reactors, optimizing conditions, and ensuring safety.

Factors Influencing Decomposition Time

While the calculation appears straightforward, several factors can influence the actual decomposition rate and time:

- Temperature Variations: Since rate constants are temperature-dependent, deviations from 500°C would alter k and, consequently, the time.
- Reaction Environment: Presence of catalysts, inhibitors, or impurities can

modify kinetics.
- Sample Homogeneity: Uniform temperature and mixing ensure consistent decomposition.
- Measurement Accuracy: Precision in initial concentration and rate constant affects calculations.

Practical Applications and Significance

Understanding the kinetics of decomposition reactions is critical in many industrial and scientific contexts:

- Pharmaceutical Stability: Ensuring drugs decompose at predictable rates to maintain efficacy.
- Polymer Degradation: Designing materials that withstand certain conditions without premature breakdown.
- Chemical Manufacturing: Optimizing reaction times to maximize yield and safety.
- Environmental Science: Predicting pollutant breakdown in the environment.

By accurately calculating reaction times, industries can improve safety protocols, optimize process efficiency, and reduce costs.

Conclusion

Predicting how long a chemical reaction takes to reach a certain extent of decomposition is essential for controlling and optimizing chemical processes. Through the principles of first-order kinetics, chemists can determine that approximately 260 seconds are needed for 90.8% of a 0.500 M sample to decompose at 500°C, given a rate constant of 9.2 × 10-3 s-1. This calculation demonstrates the power of kinetic analysis in practical applications, ensuring that processes are predictable, safe, and efficient. As temperature and other factors influence reaction rates, ongoing research and measurement are vital to refine these predictions, supporting advancements across various scientific and industrial fields.

The Rate Constant For The First Order Decomposition Of A At 500oc Is 9 2 X 10 3 S 1 How Long Will It Take For 90 8 Of A 0 500 M Sample Of A To Decompose

The Rate Constant For The First Order Decomposition Of A At 500oc Is 9 2 X 10 3 S 1 How Long Will It Take For 90 8 Of A 0 500 M Sample Of A To Decompose

Related Articles

- Which Of The Following Budget Methods Provides A Quick Start To The Budget Development Process? Roll-upComparisonReservesActual
- The Table Below Shows The Earnings, In Thousands Of Dollars, For Three Different Commissioned Employees.Employee
- If One DNA Strand Reads ATCCCGAG The Other Strand Will Be Made Up Of The Complementary Bases A.TAGGGCTCb.TAGGGCTGc.TACCCGTCd.ATGGGCTC

Back to Home